**1) Atherosclerosis of carotid artery**

Atherosclerosis is characterized by local thickening of inner artery walls caused by invasion and accumulation of white blood cells. High cholesterol content in the blood (low-density lipoproteins) is one of the risk factors for this disease. Arterial stenosis and complete obstruction are the consequences. Carotid arteries, one of the main arteries of cerebral blood supply, are prone to the development of such plaques.

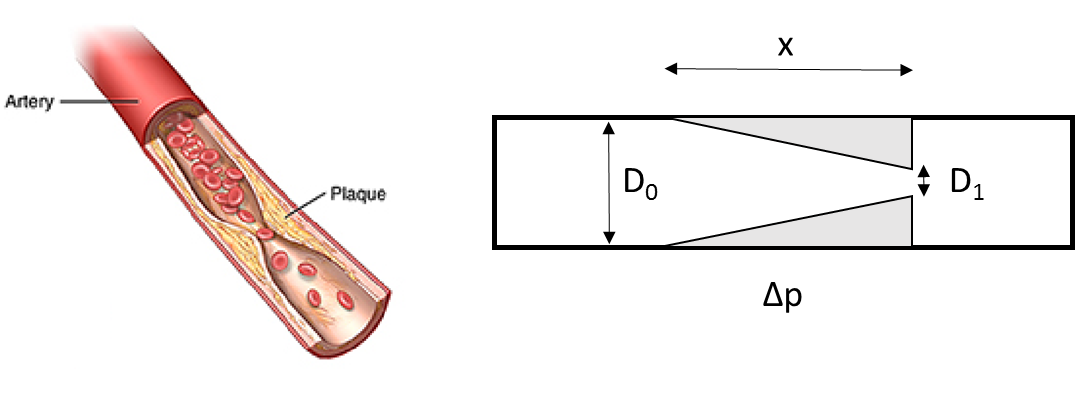


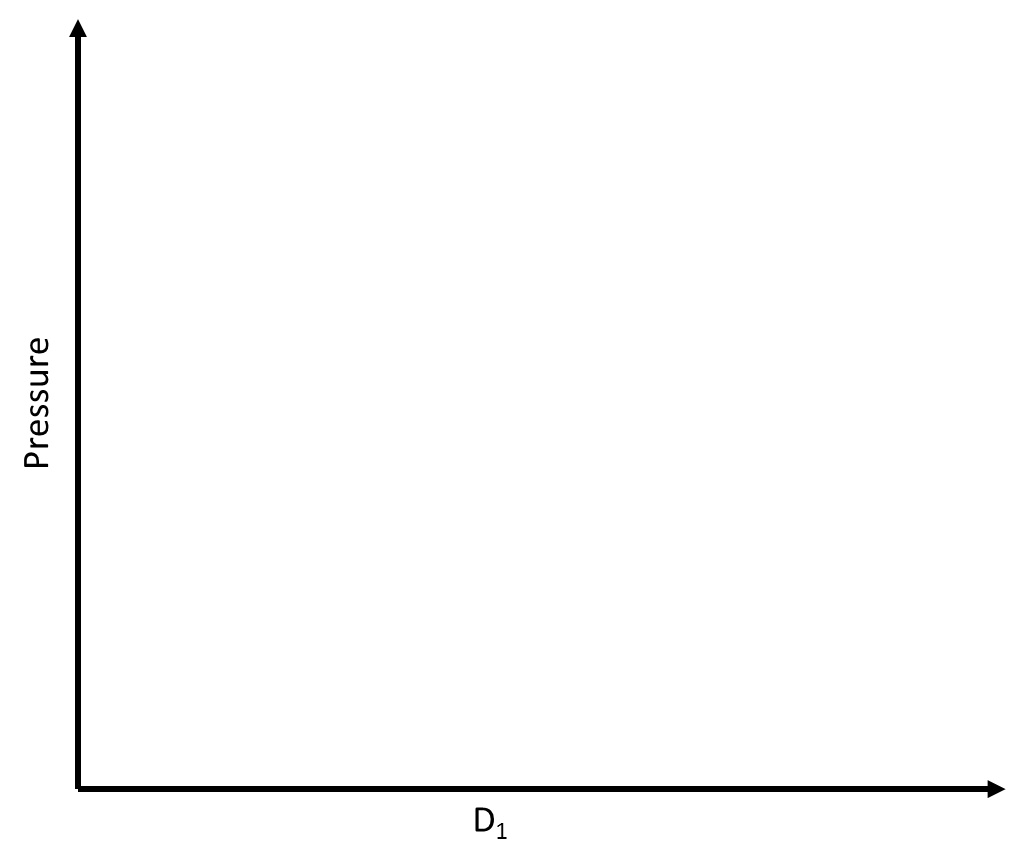
Figure 1

Figure 1 shows an atherosclerotic plaque and an idealized cross-section of the artery.

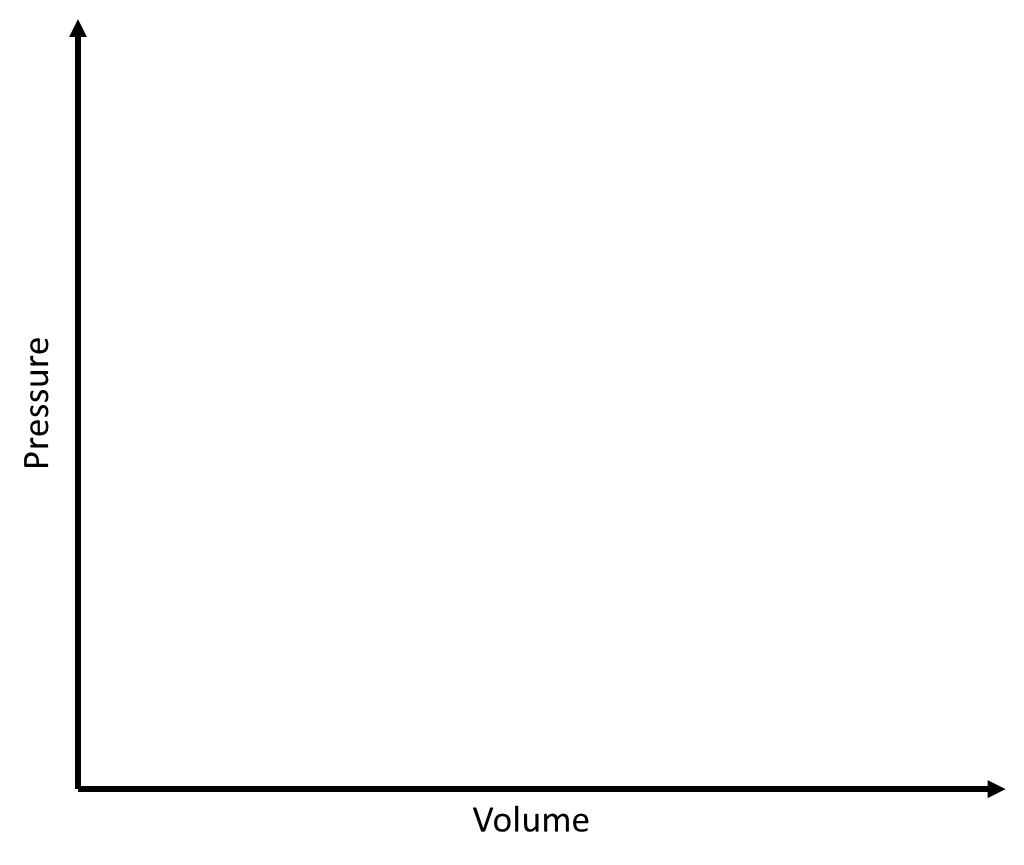
Plaque accumulation results in an increased pressure-drop. In the extreme case clinical intervention is needed.

a) Derive a formula from the Hagen-Poiseuille-Law that calculates the increased pressure depending on the diameter D1. Due to fluid-mechanical phenomena, the relationship between plaque length and plaque height is length/height=5. **Hint:** Also consider pressure loss during the plaque-free state.

b) Sketch (qualitatively) the relationship between pressure increase Δp and the diameter D1 and calculate plaque length and height for the case Q=300 ml/min, D0=4.7mm, η=3.6mPas and Δp=40 mmHg. Insert the results in the graph.



c) Sketch (qualitatively) two LV-PV loops into the diagram below. One for the healthy state and one for the state of a stenosed artery. Mark the EDV, ESV, SW, ESPVR and EDPVR.



d) Angioplasty with stenting can help to reduce the obstruction of the vascular cross-section. Therefore a stent is inserted and expanded to lower the height of the plaque.

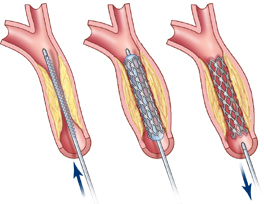
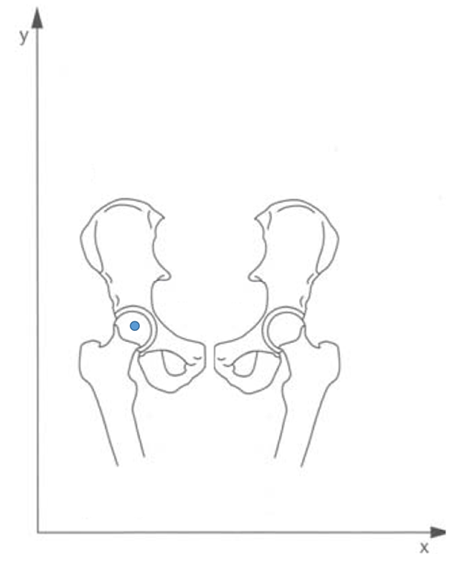


Figure 2

Calculate the expansion diameter of the stent to ensure a reduction of pressure from 40 mmHg to 5 mmHg. Mark the new D1 and Δp in the graph of 1b). Draw the LV-PV loop that will develop **directly** after the intervention into the graph of 1c)

**2) Hip force reduction with walking stick**

Use of a walking stick on the contralateral side of the joint (marked with the blue dot) can reduce the joint forces. Show that the joint force H will be reduced when a walking stick is used.



**3) Oxygen transport from alveolus to capillary**

Oxygen transfer from lungs to blood is characterized by a diffusion process from the alveoli to the capillaries. The left side of figure 3 shows an alveolus with a constant oxygen concentration calv and a capillary with the oxygen concentration ccap changing along the axial direction of the capillary. Diffusion is a dynamic process, therefore oxygen concentration is dependent on the contact length between capillary and alveolus.



Figure 3

Length specific mass transfer (mass flow/length) from alveolus to the capillary is characterized by (a modified) Fick’s law. D is a diffusion coefficient [m3/s]. z is the thickness of the diffusion barrier. Ci are the according concentrations.

a) Determine and sketch qualitatively the functional relationship C(x) the oxygen concentration inside the capillary along the axial direction, under the given volume flow rate Q.

**Hint:** Write out the mass flow equilibrium at an infinitesimal element dx and calculate the Taylor series expansion at x+dx. Boundary condition for the ODE is C(0)=0. For the sake of conciseness sum up the known parameters under one variable.

b) Calculate the necessary flow rate Q through a capillary around an alveolus with the diameter 200 µm, such that at the end of the capillary the oxygen saturation is 95%.

D=7.85\*10-17 [m3/s], z=0.5 µm. The capillary diameter can be disregarded in comparison to the alveolus radius R. The capillary covers 180 ° of the alveolus.